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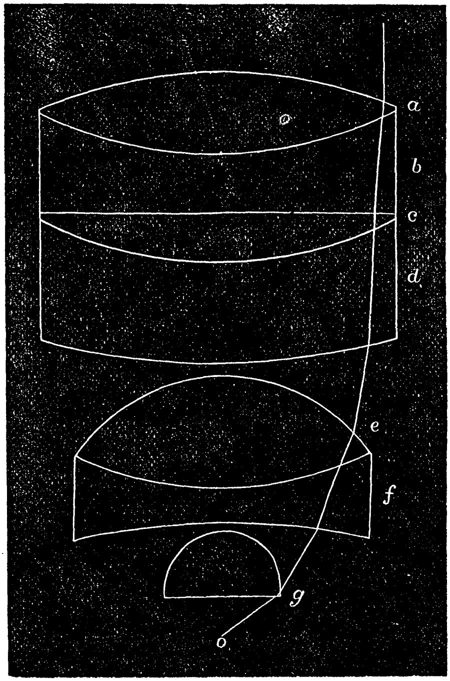
MICROSCOPY.

Angular Aperture.—The discussion upon this question which was tedious a year or two ago has become interesting now, and the utilization of the extra-limital rays (in immersion objectives as compared with dry ones) which was first published as a definite theory by Dr. Woodward, in the "Monthly Mic. Journ.," and editorially in the Naturalist, in an article which was written independently, and was in type at the same time, seems likely to prove to be one of the few great steps of progress in the development of the microscope. Before that time Mr. Wenham, and some others, had strenuously insisted upon teaching the reduction of the (nearly) 180° dry angle to about 82° immersion angle, and in so doing had been led, apparently unconscious of saying materially more than that, into a denial of the possibility of constructing an objective capable of using a larger angle than that; and Mr. Tolles, and no others, had as firmly insisted on his ability to enlarge the angle without any definite or assignable limit: the one party had argued a natural limit and nothing further, and the other party had denied a limit and appealed to his work for proof, but neither party was understood to have established the doctrine of the utilization of the extra-limital rays by admitting the limit, and at the same time showing how that limit may be passed without conflicting with well established theory. When this explanation was published it seemed so reasonable and so consistent with the assertions of both parties, that it was supposed both would say that it was precisely what they meant all the time. Mr. Tolles promptly did this, but Mr. Wenham, to the surprise of many of his friends, denied and still denies the whole doctrine, and what is more strange is satisfied with a measurement of one of Mr. Tolles' glasses as a final disproof of so fundamental and important a theory. The exact angle of a certain $\frac{1}{6}$ made by Mr. Tolles, and whether it exceeds 82° or not, is of some consequence to Mr. Tolles and his customers, but is of little importance to the world of science, compared with the theoretical possibility of exceeding that limit; and Mr. Wenham is, perhaps, one of the last persons in the world who would have been expected to fall into any doubt or confusion at this point. At the same time as Mr. Tolles was the first, and still is the only one known to claim to make lenses in which the extra-limital rays are turned to good account, it is only justice to him to mention his name in connection with them, just as Huyghens and Kellner are credited with the negative and orthoscopic oculars, and Wenham with the binocular prism and the simple front objective. The exact comparative efficiency of the extra-limital immersions is yet undetermined, though they would be expected to have certain strong working points; a theory that seems fully justified, even after making all possible allowance for the enthusiasm of those possessing and using a novelty, by the trials already made of some of the lenses.

Fig. 24.



Of all the contributions to this subject none probably excel in interest and importance the mathematical computation of the course of the light through the $\frac{1}{10}$ inch objective at the Army Medical Museum, by Prof. R. Keith, of Georgetown, a synopsis of which was published in the September Number of the "Monthly Microscopical

Journal," and for the full details of which we are indebted to the courtesy of Prof. Keith. Nor is the interest of this elaborate mathematical analysis appreciably lessened by Mr. Wenham's doubt, as to the reliability of the data furnished by Mr. Tolles as a basis for the computation; since if the data do not accurately represent the construction of that objective they at least seem to represent a practicable combination of lenses, which might be made into an objective, and that is what we want to know, and what the long discussion has derived its cat-like life from. The objection in question consists of seven lenses; a quadruple back consisting of a double-convex of crown glass, a plano-concave of flint, a plano-convex of crown and a meniscus of flint, a double middle formed by the union of a double-convex of crown and a double-concave of flint, and a simple hemispherical front of crown. The plan of grinding the lenses as thin as possible is discarded, as in much recent work, and some of the lenses are quite thick at the thinnest point. The following figures represent the data of construction, the letters *a* to *g* representing the seven lenses in regular order, beginning with the upper lens of the back combination (See also Fig. 24).

	a.	b.	c.	d.	e.	f.	g.
Index of Refraction.	1·525	1·620	1·525	1·620	1·525	1·654	1·525
Radius of Curvature:							
First surface.	·265	·2	∞	·2	·1	·18	·033
Second surface.	·2	∞	·2	·5	·18	·5	∞
Thickness at centre.	·048	·027	·033	·047	·062	·02	·035
Diameter.	·2	·2	·2	·2	·165	·165	·066

Distance of back combination from middle, ·008. By screw collar adjustment the front is set at a distance of ·00528 from the next surface. The light is assumed to start from a point ten inches above the first (back) surface, and is traced through the objective to a focal point below. The table on p. 62 represents the distance from the axis at which the extreme ray crosses each surface, and the angles which the ray, before crossing, makes with the axis. The negative sign indicates convergence of light.

This gives a computed angular aperture of 110° 35′ 10″, which largely exceeds the 87° obtained by measurement by Dr. Woodward; but the very reasonable allowance of ·00162 for the setting of the front lens, reduces the computed to the observed angle. By computation the spherical aberration is almost nothing, which also corresponds with Dr. Woodward's statement, based upon the performances of the lens in actual use. Though constructed for immersion use only, Dr. Woodward states that it works well dry at near open point.

First surface.	0·09250	+ 0° 31′ 45″
Second "	0·09139	— 6 51 51
Third "	0·08742	— 4 37 23
Fourth "	0·08626	— 4 54 42
Fifth "	0·08318	— 2 57 30
Sixth "	0·07391	— 11 1 3
Seventh "	0·06625	— 24 37 5
Eighth "	0·05324	— 20 8 0
Ninth "	0·03300	— 29 44 7
Tenth "	0·00000	— 55 17 35

TOLLES' NEW $\frac{1}{10}$TH *vs.* OLD $\frac{1}{50}$TH.[1]—I am indebted to my friend Mr. J. Edwards Smith, of Ashtabula, O., for the loan of his old Tolles' $\frac{1}{10}$th, the first lens, so far as I know, that showed *A. pellucida* in dots, and also his new Tolles' $\frac{1}{6}$th objective. Both glasses failed in my hands, with eye-pieces as high as Beck's No. 3, to do as well as my Tolles' 3 system $\frac{1}{50}$th: but the performance of the $\frac{1}{6}$th was so very fine for a glass of such low power, that I at once ordered one of like construction; thinking that such a glass could be relied upon in the study of objects too thickly covered to permit the use of the higher-power objective.

The one sold me by Mr. Stodder is marked "Tolles' $\frac{1}{10}$th Immersion, Balsam angle 88°." Its air angle, as billed by Mr. Stodder, is 180°. It works well through the covers generally used for test objects.

I was greatly surprised at the exquisite performance of this glass. The best work of the $\frac{1}{50}$th, either by day or lamplight illumination, was at once excelled; the advance being of so decided a character as not to permit of doubt.

A certain Lepisma scale that I had carefully studied for a long time with the $\frac{1}{50}$th and other glasses, and had seen under many favorable conditions, was instantly displayed by the four-system $\frac{1}{10}$th clearer and better in every respect than I had before seen it. With this superb definition it appeared in ridges and corrugations, not beads; thus confirming the conclusions arrived at previously.

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[1] Read before the Memphis, Tenn., Microscopical Society, Dec. 3d.

The superiority of the new glass is also evident on the most difficult natural tests known, such as *A. pellucida*, *N. crassinervis*, *F. saxonica* and *Nitzschia curvula*, the transverse striæ showing well, by lamplight, on all of them whether mounted dry or in balsam. The longitudinal lines of *Suirella gemma* are strongly seen; and such coarsely marked shells as *P. angulatum*, are splendidly illustrated with central light. This method of illumination readily brings to view the minute hexagons of *Triceratium favus* in balsam, a more difficult test than *angulatum;* and also shows *S. gemma* well broken up.

An exquisite definition of the scales of *Podura* and *Degeeria*, gives no semblance of beading, although the ridges are better defined than I have ever seen them before.

For an eminent optician to surpass his own best glasses of the highest powers, with objectives of an improved plan of construction and of as low power as $\frac{1}{10}$th, is surely a triumph worth recording, and gives promise of still further advance.—G. W. MOREHOUSE, *Wayland*, *N. Y.*, *Nov.*, 1874.

REMARKS ON MR. MOREHOUSE'S PAPER.[1] — Referring to Mr. Morehouse's observations on *Podura* and *Lepisma*, I desire to say that I have diligently studied these scales with the new 4 system $\frac{1}{6}$th and $\frac{1}{10}$th objectives, and that I thoroughly endorse what he has written. I have never discovered the slightest semblance of the "beading" set forth by some observers. With the objective out of proper correction, it is indeed easy to get appearances that might mislead a novice.

Regarding the performance of the $\frac{1}{6}$th, I beg to add, that its maximum cannot be obtained with eye-pieces less than a *D* solid. Even when employing lamp illumination, I often get "decided added force" by using the $\frac{1}{4}$th inch solid (=F). With blue sunlight the $\frac{1}{6}$th will bear the $\frac{1}{8}$th inch solid effectively.—J. EDWARDS SMITH, *Ashtabula*, *O.*, *Nov.*, 1874.

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[1] Read before the Memphis Microscopical Society, Dec. 3d.